BWR Vessel and Internals Project LPCI Coupling Repair Design Criteria (BWRVIP-56NP)

REPORT SUMMARY

The Boiling Water Reactor Vessel and Internals Project (BWRVIP), formed in June, 1994, is an association of utilities focused exclusively on BWR vessel and internals issues. This BWRVIP report documents criteria which can be used to design a repair for LPCI Couplings in a BWR.

Background
In the event that significant degradation is observed in a BWR LPCI Coupling, repair may be required. Utilities need criteria which can be used in the development of designs for those repairs.

Objectives
To compile the appropriate repair design criteria into a document which can be used by utility personnel performing the design and which could be submitted to appropriate regulatory agencies for approval of the generic design process.

Approach
The contractor assembled a draft document which discussed all elements which need to be considered in designing a repair. Items discussed include: design objectives; structural evaluation; system evaluation; materials, fabrication and installation consideration; and, required inspection and testing. The resulting draft was reviewed in depth by BWRVIP utility representatives as well as third party contractors. The final report incorporates comments received during those reviews.

Results
The document provides general design acceptance criteria for the repair of a LPCI Coupling. Repairs designed to meet these criteria will maintain the structural integrity of the component under normal operation as well as under postulated transient and design basis accident conditions.

EPRI Perspective
The criteria listed in the report define a standard set of considerations which are important in designing a repair. It is intended that these criteria will be submitted to the USNRC, and possibily non-US regulators, for their approval. Regulatory acceptance of these generic criteria will significantly reduce the utility effort required to obtain approval for plant-specific repairs.

TR-108717NP

Key Words
Boiling Water Reactor
Repair
Stress Corrosion Cracking
Vessel and Internals
LPCI Coupling

BWR Vessel and Internals Project
LPCI Coupling Repair Design Criteria

(BWRVIP-56NP)

TR-108717NP
Research Project B501

Final Report, March 2000

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GE Nuclear Energy

BWRVIP Repair Committee

Prepared for

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ORDERING INFORMATION

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Executive Summary

The Boiling Water Reactor Vessel and Internals Project (BWRVIP) was formed in June 1994 as a utility-directed initiative to address BWR vessel and internals issues. This criteria document was developed by the Repair Technical Subcommittee of the BWRVIP.

This document provides the general design acceptance criteria for temporary and permanent repair of BWR low pressure coolant injection (LPCI) couplings. It is provided to assist BWR owners in designing repairs which maintain the structural integrity of the LPCI coupling during normal operation and under postulated transient and design basis accident conditions for the remaining plant life or other service life as specified by the plant owner.

Issuance of this document is not intended to imply that repair of the LPCI coupling is the only viable method for resolving cracking in the components. Due to variation in the material, fabrication, environment and as-found condition of the individual LPCI couplings, repair is only one of several options that are available. The action to be taken for individual plants will be determined by the plant licensee.

1. INTRODUCTION

1.1 Background

Recently, the BWRVIP prepared a safety assessment of BWR internals [1]. As documented in this safety assessment, the low pressure coolant injection (LPCI) coupling is an internal component which can tolerate extensive degradation. The BWRVIP have also prepared generic inspection and evaluation guidelines [2] to assure the continued safety function integrity of the LPCI coupling. This repair design criteria has been developed to prepare for the potential situation in which a repair of an LPCI coupling is needed.

1.2 Purpose

The purpose of this document is to provide general design guidance and acceptance criteria for permanent and temporary repair of cracked or leaking LPCI couplings.

The issuance of this document is not intended to imply that a repair of the LPCI coupling is the only viable disposition of such cracking/degradation.

1.3 Scope

This document is applicable to General Electric BWR/4 through BWR/6 plants which plan to implement repairs to the LPCI coupling.

2. DEFINITIONS

Repair	Repair as used in the context of this document is a broad term that applies to actions taken to design, analyze, fabricate and install hardware that restores the structural and functional integrity of all or a portion of the LPCI coupling. Weld overlay, without removal of the defect, is also a repair in the context of this criteria. Similarly, full or partial replacement of the LPCI coupling is considered a repair option.

3. LPCI COUPLING CONFIGURATIONS AND SAFETY FUNCTIONS

3.1 General Physical Description

This section describes the various BWR LPCI couplings and their functions. The criteria of this report are generic in nature. Efforts have been taken to identify the various configurations, differences in materials, etc. between different plant types. However, it is the responsibility of the BWRVIP member utilities to verify their specific plant configurations for applicability with respect to the descriptions, materials, figures and tables given in this document.

3.1.1 Function of the LPCI Coupling

When in the Low Pressure Coolant Injection (LPCI) operating mode the Residual Heat Removal (RHR) System is part of the Boiling Water Reactor (BWR) Emergency Core Cooling System (ECCS). The purpose of the LPCI operating mode is to restore and maintain the desired water level inside the reactor shroud in the unlikely event of a loss of coolant accident (LOCA). The purpose of the LPCI coupling is to provide a hydraulic path through a flexible joint between the RHR/LPCI nozzle on the reactor vessel and the shroud cylinder in which low pressure core flooding water flows. This component is not generally used during normal operation. During a reactor safe shutdown operation, the LPCI mode can be used to provide the alternate shutdown cooling if the Shutdown Cooling mode of RHR System is unavailable due to loss of its normal suction path from the reactor.

The LPCI coupling is a reactor internal component with a safety function. LPCI couplings are applicable to newer BWR/4 plants, BWR/5 and BWR/6 plants.

3.1.2 LPCI Coupling in BWR/4 and BWR/5 Plants

The newer BWR/4 and the BWR/5 plants have essentially identical couplings. Typical coupling arrangement and details are shown in Figures 1 through 10. There are four coupling assemblies per newer BWR/4 plant and three coupling assemblies per BWR/5 plant. The internal piping arrangement in these plants discharges the flow into the shroud in the upper shroud region, at the top guide elevation. The coupling extends horizontally from the vessel to the shroud. The coupling sleeve is designed to be removable and is attached by V-groove band clamps to flanges fixed at the shroud and at the reactor pressure vessel (RPV) nozzle safe end/thermal sleeve. The coupling itself could be bellows-type or sleeve-type. However, due to susceptibility to IGSCC, the bellows-type couplings have been replaced with the sleeve type in all applicable plants in the United States (Bellows-type couplings exist in two plants outside of the United States). Bellows-type coupling assemblies have not been reviewed and are not included as part of this repair design criteria. A slip joint is located at each end of the coupling sleeve. Piston ring seals are included at the flange/sleeve slip joints to minimize leakage flow. Stellite #6 is applied to the contact surface of the sleeve and the flange to provide a hard contact surface and facilitate relative motion at the contact. A typical baffle/channel arrangement exists inside the shroud which serves to direct the LPCI flow under the top guide and into the core area. Typical baffle arrangement is shown in Figures 9 and 10.

While the BWR/4/5 LPCI couplings are generally very similar, there are some differences in the design, fabrication conditions, and materials that exist in the different BWR/4/5s. The variations of the hardware configurations and materials among the BWR/4/5 plants are summarized in Table 1.

Table 1: BWR/4/5 LPCI Coupling Materials & Configuration

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3.1.3 LPCI Coupling in BWR/6 Plants

There are three LPCI coupling assemblies per BWR/6 plant. Typical coupling arrangement and details are shown in Figures 11 through 17. The arrangement in the RPV-Shroud annulus consists of two elbows (the upper one connected to the RPV safe end and the lower one connected to the shroud) just below the flange which seats the top guide. The components connecting the two elbows include a fitting welded to the ends of the elbows and a sleeve coupling interface between the elbows, the ends of which are housed inside collars which are threaded to the fittings. This provides a slip joint at each end of the sleeve. Piston ring seals are included at the collar/sleeve slip joints to minimize leakage flow. Stellite #6 is applied to the contact surface of the sleeve and the collar to provide hard contact surface and facilitate relative motion at the contact. In order to minimize flow-induced vibration effects, a strut is welded to the lower elbow, bracing it to the shroud. The injection point inside the shroud is directed to a location below the top guide grid. A flow diverter exists at the inlet inside the shroud, which consists of a flow directing splash plate with four legs welded to the shroud inner wall. The diverters were added because an optional return path during shutdown cooling uses the LPCI line. The diverters were added as a part of a modification designed to reduce the impact of flow induced vibration on the reactor internals during LPCI flow injection. A typical flow diverter is shown in Figure 17.

While the BWR/6 LPCI couplings are generally very similar, there are some differences in the design, fabrication conditions, and materials that exist in the different BWR/6s. The variations of the hardware configurations and materials among the BWR/6 plants is summarized in Table 2.

Table 2: BWR/6 LPCI Coupling Materials and Configuration

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3.1.4 RHR LPCI Mode Vessel Nozzle

The configuration of the RHR LPCI Mode vessel nozzle are plant specific. One typical RHR LPCI Mode vessel nozzle is shown in Figure 18. In this typical nozzle an alloy 600 tuning fork safe end is used as a transition between the low alloy steel vessel nozzle and a carbon steel safe end extension which corresponds with the drywell piping. The 304 stainless steel nozzle thermal sleeve includes an alloy 600 extension piece which allowed the field weld of the thermal sleeve to the safe end to be made with similar metals.

3.2 Safety Design Bases

3.2.1 LPCI Coupling

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3.2.2 Loose Parts

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3.3 Event Analyses

The purpose of this document is to provide general design criteria for repair of the LPCI coupling. Accordingly, various events and operational conditions must be considered to ensure that the repair does not inhibit the ability of the LPCI coupling to perform their basic safety functions. The following general load cases shall be considered in the design of the proposed repair.

3.3.1 Normal Operation

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3.3.2 Anticipated Operational Occurrences (Upset Conditions)

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3.3.3 Design Basis Accidents (Emergency/Faulted Conditions)

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3.3.4 Loading Combinations

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4. SCOPE OF REPAIRS

The LPCI coupling repairs primarily address cracking and/or leaking in IGSCC susceptible stainless steel and nickel-chrome-iron alloy components of the LPCI coupling assembly. The scope of the LPCI coupling repair criteria includes: the vessel nozzle thermal sleeve, the flanges, the coupling itself, the elbows (BWR/6), extension sections, the shroud attachment hardware items illustrated in this report and the baffle/flow deflector.

5. DESIGN OBJECTIVES

5.1 Design Life

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5.2 Safety Design Bases

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5.3 Safety Analysis Events

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5.4 Structural Integrity

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5.5 Retained Flaw(s)

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5.6 Loose Parts Considerations

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5.7 Physical Interfaces with Other Reactor Internals

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5.8 Installation Considerations

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6. DESIGN CRITERIA

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6.1 LPCI Coupling Design

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6.2 Reconciliation With ASME Code Components

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7. STRUCTURAL AND DESIGN EVALUATION

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7.1 Load Definitions - Applied Loads

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7.2 Service Level Conditions

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7.3 Load Combinations

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7.3.1 Mark I Plants

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7.3.2 Mark II and III Plants

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7.4 Functional Evaluation Criteria

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7.5 Allowable Stresses

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7.6 Flow Induced Vibration

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7.7 Repair Impact on Existing Internal Components

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7.8 Radiation Effects on Repair Design

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7.9 Analysis Codes

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7.10 Thermal Cycles

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7.11 Corrosion Allowance

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Table 3: Load Combinations for Mark I Plants

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Table 4: Load Combinations for Mark II and Mark III Plants

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Table 5: Load Term Definitions for Tables 3 and 4

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8. System Evaluation

8.1 Leakage

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8.1.1 Leakage Impact - Normal Operation

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8.1.2 Leakage Impact - Accident Conditions

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8.1.3 Leakage Acceptance Criteria - LPCI Coupling

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8.2 LPCI Coupling Pressure Drop

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8.3 Impact to Flow Distribution

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8.4 Emergency Operating Procedure (EOP) Calculations

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9.3 Welding and Fabrication

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10.2 Pre and Post Installation Inspection

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11. QUALITY ASSURANCE PROGRAM

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12. Documentation

The following documentation shall be prepared and maintained by the utility as permanent records:

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13. REFERENCES

[1] EPRI Report TR-105707, "BWR Vessel and Internals Project, Safety Assessment of BWR Reactor Internals," (BWRVIP-06), October 1995.

[2] EPRI Report TR-108726, "BWR Vessel and Internals Project, LPCI Coupling Inspection and Flaw Evaluation Guidelines (BWRVIP-42)," December 1997

[3] EPRI Document 84-MG-18, "Nuclear Grade Stainless Steel Procurement, Manufacturing and Fabrication Guidelines", Rev. 2, January 1986

[4] EPRI Document NP-7032, Material Specification for Alloy X-750 for Use in LWR Internal Components, Revision 1

[5] Code Case N-516, "Underwater Welding Section XI, Division", Approved August 9, 1993

14. FIGURES

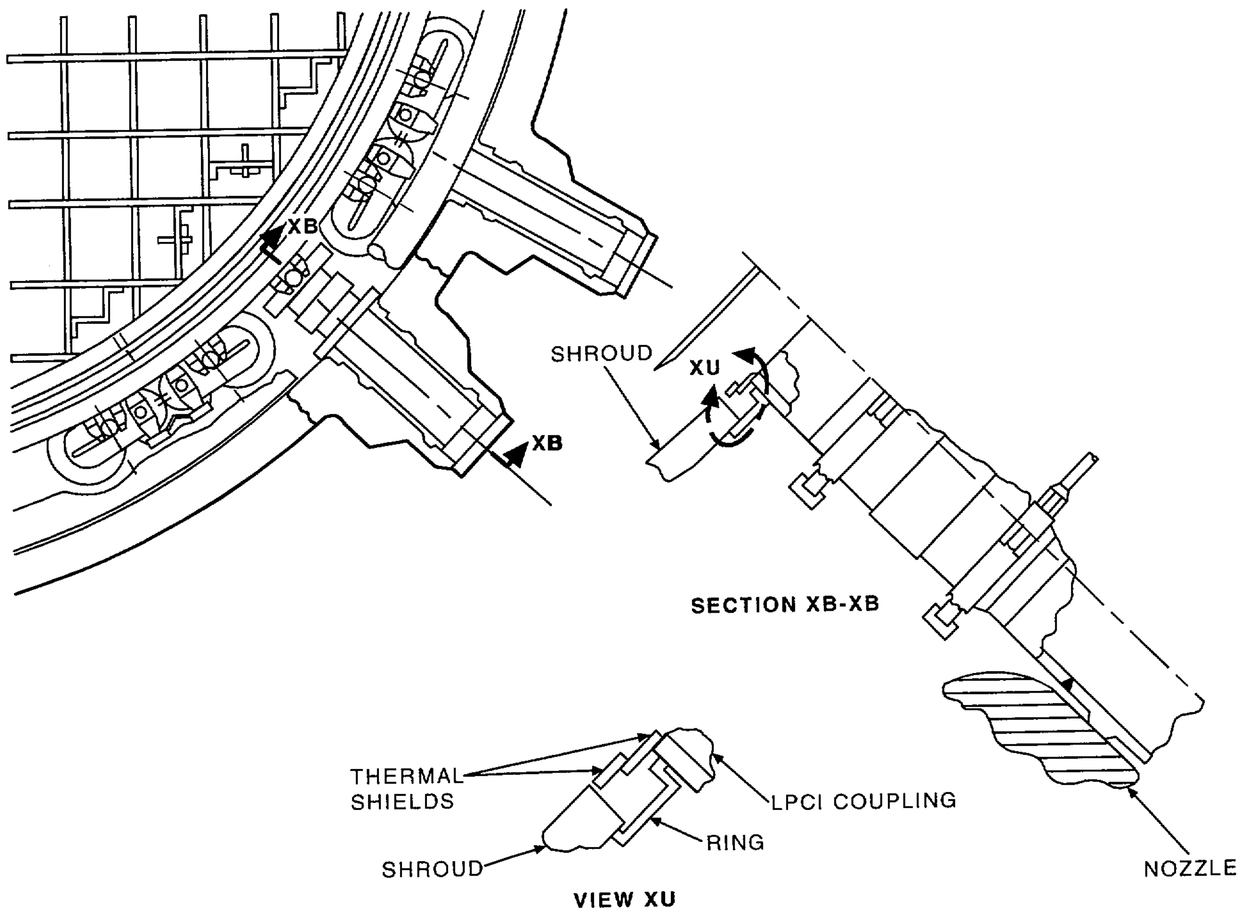

Figure 1: Typical LPCI Coupling Arrangement - BWR/4/5

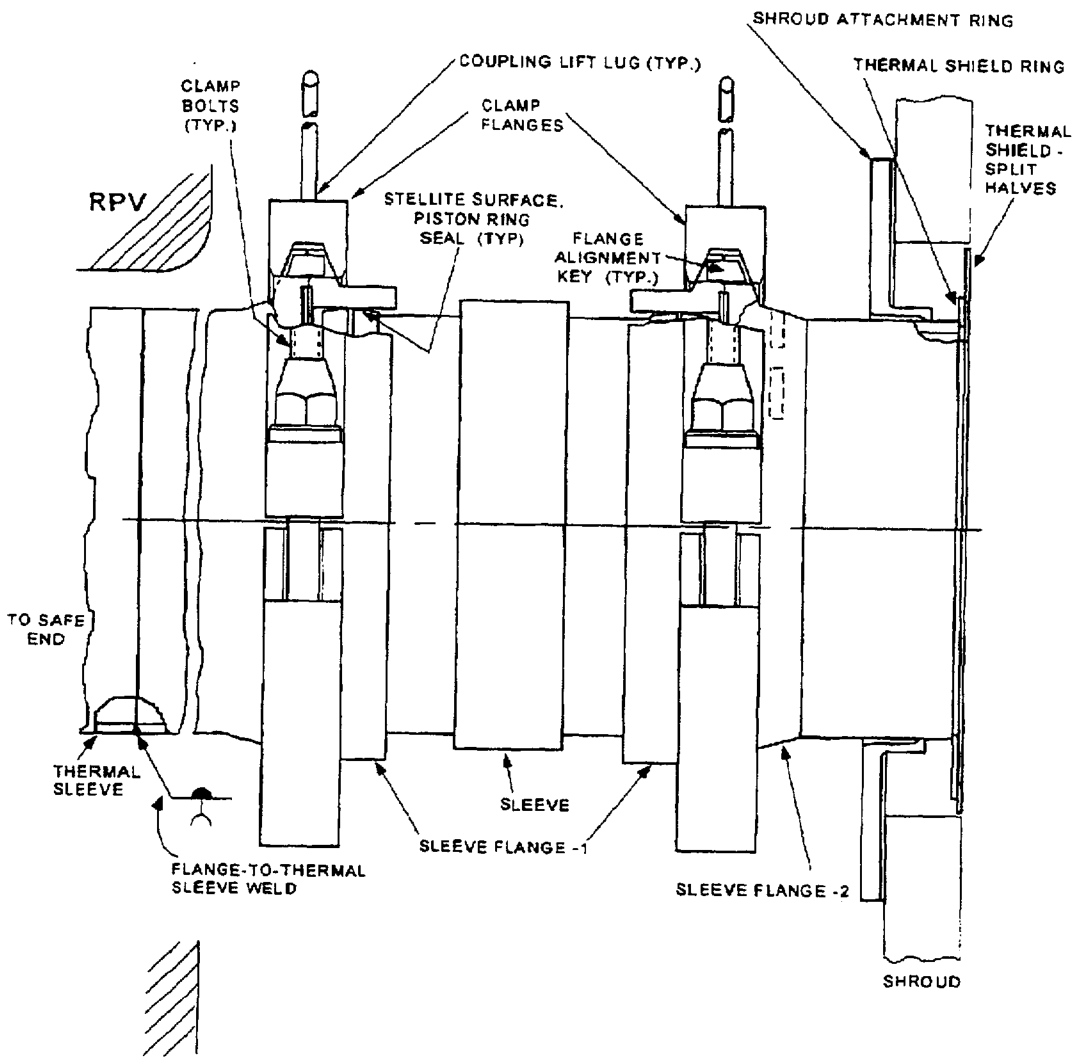

Figure 2: Typical LPCI Coupling - BWR/4/5

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Figure 3: LPCI Coupling Details - BWR/4/5 Thermal Shield

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Figure 4: LPCI Coupling Details - BWR/4/5 Shroud Attachment Ring

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Figure 5: LPCI Coupling Details - BWR/4/5 Sleeve Flange - 1

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Figure 6: LPCI Coupling Details - BWR/4/5 Sleeve Flange 2

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Figure 7: LPCI Coupling Details - BWR/4/5 Clamp & Eye Bolt

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Figure 8: LPCI Coupling Details - BWR/4/5 Coupling Sleeve

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Figure 9: LPCI Coupling Details - BWR/4/5 Baffle Arrangement

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Figure 10: LPCI Coupling Details - BWR/4/5 Baffle Welds

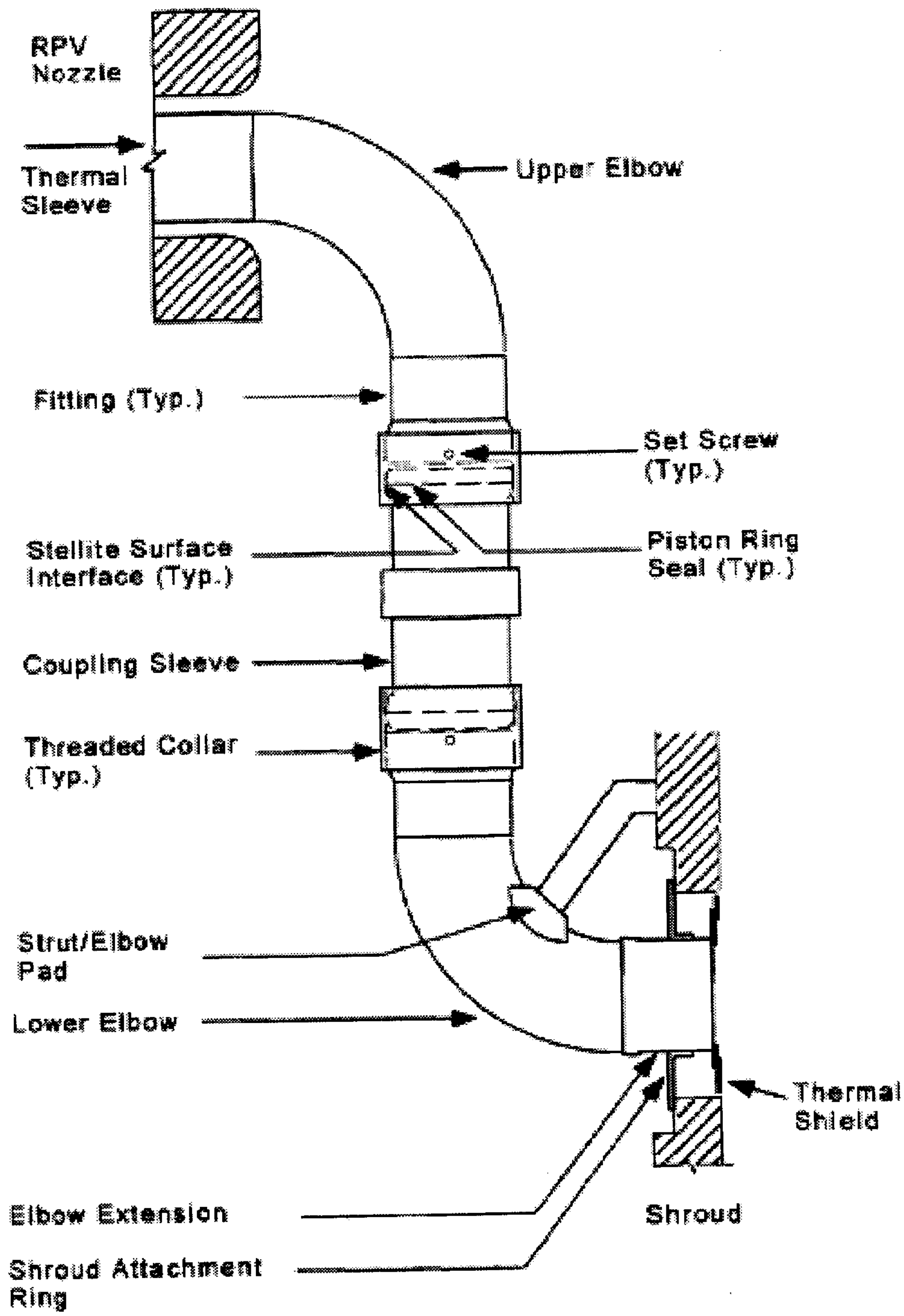

Figure 11: Typical LPCI Coupling - BWR/6

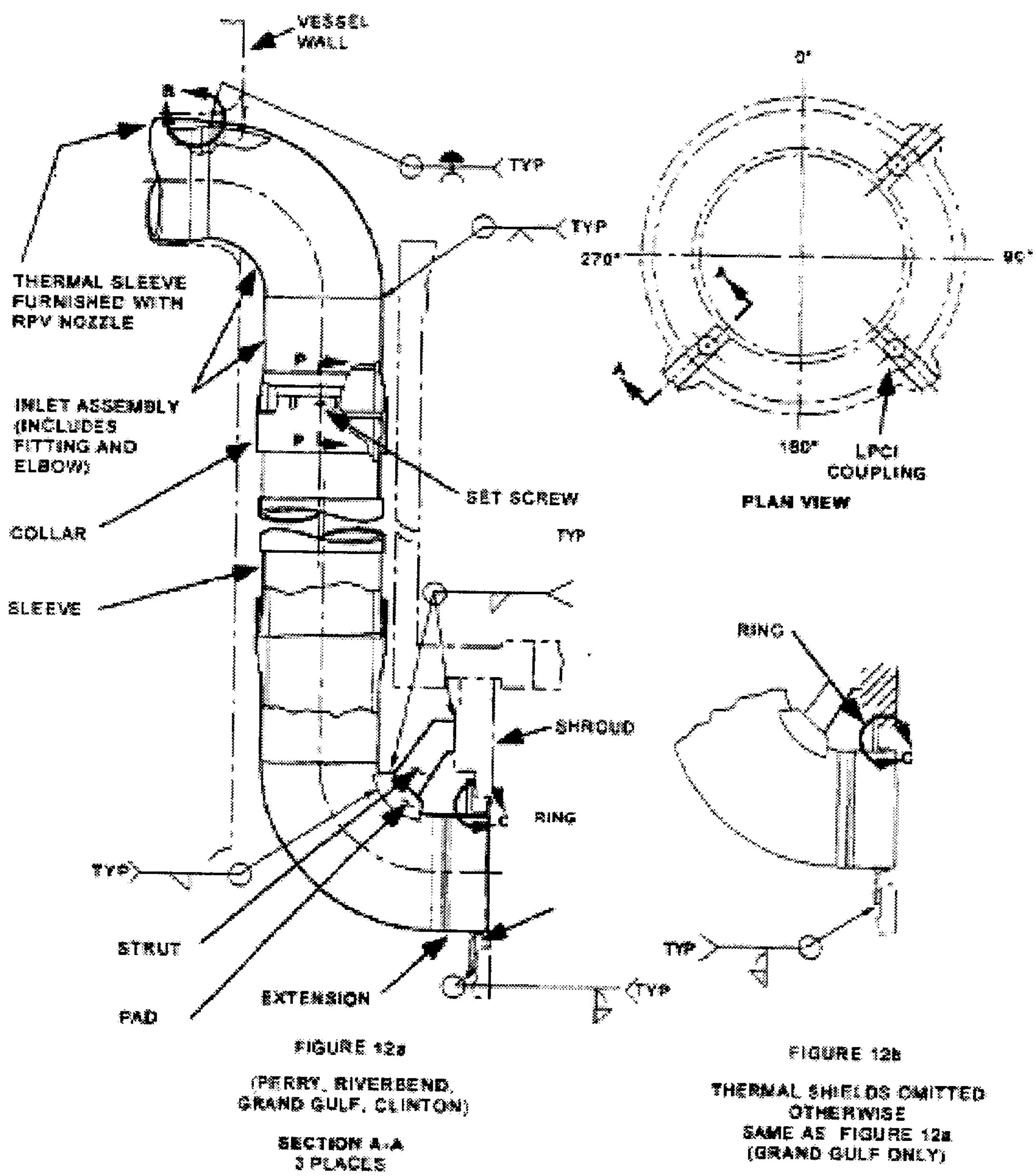

Figure 12: Typical LPCI Coupling - BWR/6 General Arrangement

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Figure 13: LPCI Coupling - BWR/6 Details

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Figure 14: LPCI Coupling - BWR/6 Thermal Sleeve

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Figure 15: LPCI Coupling - BWR/6 Shroud Attachment Flange

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Figure 16: LPCI Coupling - BWR/6 Coupling Sleeve

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Figure 17: LPCI Coupling - BWR/6 Flow Diverter

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Figure 18: Typical LPCI Vessel Nozzle BWR/4/5/6

APPENDIX A - REPAIR CONCEPTS

There have been no known failures of BWR LPCI couplings and there are no known documented specific repair concepts. However, some concepts which might be applicable are discussed below.

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Target:
Nuclear Power

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